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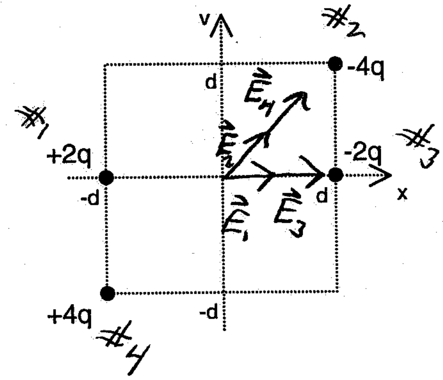
Name: ______________________

Recitation Instructor: **Dick** **Jane** **Sally** **Spot** **Pete**

Problem 1, 30 points total. Consider the four charges shown in the figure. The value of each charge and its position are labeled.



(a) 15 points. What is the electric field, $\vec{E}$, at the origin?

$$\vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 + \vec{E}_4 = 2\vec{E}_1 + 2\vec{E}_4$$

$$\vec{E}_1 = \frac{k(2q)}{d^2}\,\hat{i}$$

$$\vec{E}_2 = \frac{k(4q)}{(\sqrt{2}d)^2}\left(\cos 45^\circ\,\hat{i} + \sin 45^\circ\,\hat{j}\right)$$

$$= \sqrt{2}\,\frac{kq}{d^2}\left(\hat{i}+\hat{j}\right)$$

$$\vec{E} = (4+2\sqrt{2})\frac{kq}{d^2}\,\hat{i} + 2\sqrt{2}\,\frac{kq}{d^2}\,\hat{j}$$

(b) 5 points. What is the potential, V, at the origin? [Take V=0 at infinity.]

$$V = V_1 + V_2 + V_3 + V_4$$

$$= 0 \checkmark$$

(c) 5 points. What would be the force, $\vec{F}$, on a charge -Q at the origin?

$$\vec{F} = -Q\vec{E} = -(4+2\sqrt{2})\frac{kqQ}{d^2}\,\hat{i} - 2\sqrt{2}\,\frac{kqQ}{d^2}\,\hat{j}$$

(d) 5 points. What would be the potential energy, U, of a charge -Q at the origin? [Take U=0 at infinity.]

$$U = -QV = 0 \checkmark$$

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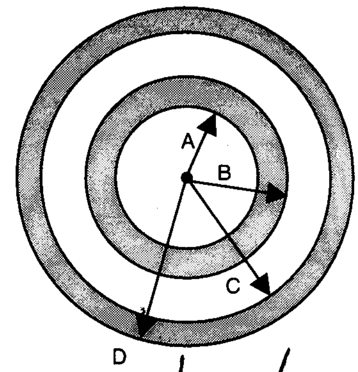
Problem 2, 30 points total. The figure shows a concentric arrangement of: a point charge; a thick, charged, conducting, spherical shell; and, a thick shell of charge. They have these specifications:

point charge: -2q

thick conducting shell: +4q, inner and outer radii of A and B.

thick charged shell: charge density +ρ, inner and outer radii of C and D.



Use a spherical Gaussian surface:

$E = \frac{1}{4\pi\varepsilon_0}\frac{q_{enc}}{r^2}$

(a) 5 points. What is $\vec{E}$ for r < A?

$q_{enc} = -2q$

$E = \frac{1}{4\pi\varepsilon_0}\frac{2q}{r^2}$ ✓ radially inward ✓

(b) 5 points. What is $\vec{E}$ for A < r < B?

$\vec{E} = 0$ ✓ Inside a conductor.

(c) 10 points. What is $\vec{E}$ for r > D?

$q_{enc} = -2q + 4q + q_o$ $q_o \equiv$ charge in outer shell

$q_o = \rho V_o = \rho\left(\frac{4}{3}\pi D^3 - \frac{4}{3}\pi C^3\right)$

$q_{enc} = 2q + \frac{4}{3}\pi\rho\left(D^3 - C^3\right)$

$E = \frac{1}{4\pi\varepsilon_0}\frac{2q + \frac{4}{3}\pi\rho\left(D^3 - C^3\right)}{r^2}$ ✓ radially outward ✓

(d) 10 points. What is the charge on the inner and outer surfaces of the conductor?

$-2q + q_{inner} = 0$

$q_{inner} = +2q$ ✓

$q_{inner} + q_{outer} = q_{cond}$

$+2q + q_{outer} = +4q$

$q_{outer} = +2q$ ✓

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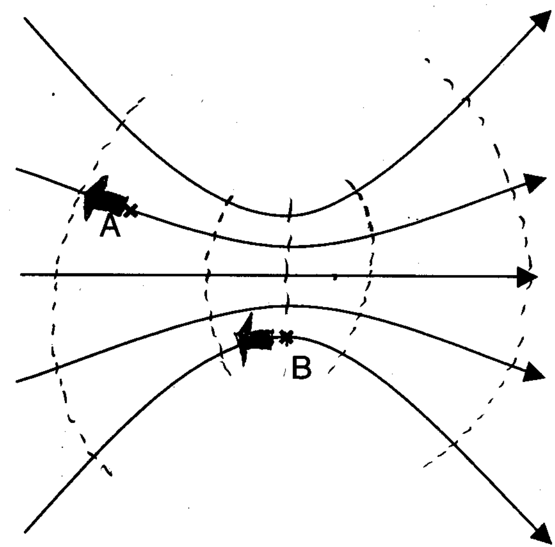
Problem 3, 20 points. The figure shows 5 field lines in a region of space. Two locations in space are indicated with x's and labeled A and B.



(a) 6 points. Draw arrows at locations A and B to indicate the direction of the force on a *negative* charge, if one was placed there.

(b) 4 points. Would the force on the negative charge be larger at A or B?

The field lines are closer at B so the field is stronger there.

(c) 6 points. Sketch equipotential lines with the same potential difference between them for this region of space. Use at least four equipotential lines distributed over the region.

(d) 4 points. Is the potential higher at A or B?

Potential drops as you go down a field line.

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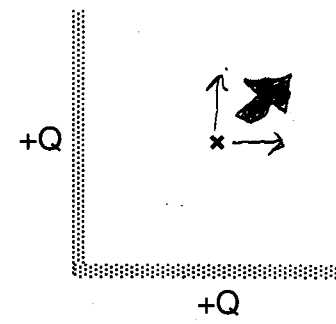
Problem 4, 20 points. Following are four unrelated short answer questions. Each is worth 5 points.

(1) The figure shows two line charges. Use an arrow to indicate the direction of the electric field at the location marked with an 'x'.

(Answer given by the thick arrow.)

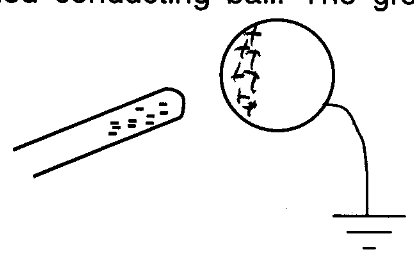


(2) How many electrons are in 2.2 μC of charge?

$$N = \frac{2.2\,\mu C}{e} = \frac{2.2\cdot 10^{-6}\,C}{1.6\cdot 10^{-19}\,C} = 1.4\cdot 10^{13}$$ ✓

(3) A negatively charged plastic rod is brought close to a grounded conducting ball. The ground connection is broken, after which the rod is removed.

Is the sphere: positively charged, neutral, negatively charged?



(4) The equipotential lines for a region of space are shown in the figure. The lines are a distance d = 2.0 m apart and the potentials are given. What is the electric field magnitude, E, in the region?

$$E = \frac{\Delta V}{\Delta x} = \frac{10\,V}{2.0\,m} = 5\ V/m$$ ✓